Quaternary Science Reviews 180 (2018) 240–259

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

New age constraints for the Saalian glaciation in northern central Europe: Implications for the extent of ice sheets and related proglacial lake systems

Jörg Lang [a, *], Tobias Lauer [b], Jutta Winsemann [a]

[a] Institut für Geologie, Leibniz Universität Hannover, Callinstraße 30, 30167 Hannover, Germany
[b] Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany

ARTICLE INFO

Article history:
Received 19 June 2017
Received in revised form
14 November 2017
Accepted 21 November 2017

Keywords:
Middle Pleistocene
Saalian glaciation
Ice-dammed lake
Lake-outburst flood
Luminescence dating

ABSTRACT

A comprehensive palaeogeographic reconstruction of ice sheets and related proglacial lake systems for the older Saalian glaciation in northern central Europe is presented, which is based on the integration of palaeo-ice flow data, till provenance, facies analysis, geomorphology and new luminescence ages of ice-marginal deposits. Three major ice advances with different ice-advance directions and source areas are indicated by palaeo-ice flow directions and till provenance. The first ice advance was characterised by a southwards directed ice flow and a dominance of clasts derived from southern Sweden. The second ice advance was initially characterised by an ice flow towards the southwest. Clasts are mainly derived from southern and central Sweden. The latest stage in the study area (third ice advance) was characterised by ice streaming (Hondsrug ice stream) in the west and a re-advance in the east. Clasts of this stage are mainly derived from eastern Fennoscandia. Numerical ages for the first ice advance are sparse, but may indicate a correlation with MIS 8 or early MIS 6. New pIRIR$_{290}$ luminescence ages of ice-marginal deposits attributed to the second ice advance range from 175 $\pm$ 10 to 156 $\pm$ 24 ka and correlate with MIS 6.

The ice sheets repeatedly blocked the main river-drainage pathways and led to the formation of extensive ice-dammed lakes. The formation of proglacial lakes was mainly controlled by ice-damming of river valleys and major bedrock spillways; therefore the lake levels and extends were very similar throughout the repeated ice advances. During deglaciation the lakes commonly increased in size and eventually drained successively towards the west and northwest into the Lower Rhine Embayment and the North Sea. Catastrophic lake-drainage events occurred when large overspill channels were suddenly opened. Ice-streaming at the end of the older Saalian glaciation was probably triggered by major lake-drainage events.

1. Introduction

During the Middle Pleistocene Saalian glaciation several advances of the Fennoscandian ice sheets reached far into northern central Europe (Fig. 1). Despite the long research history, the correlation between the different stages of ice-sheet advance and decay still remains problematic (cf., Ehlers et al., 2004, 2011; Böse et al., 2012; Lee et al., 2012) and numerical age constraints are sparse. Three major Saalian ice advances with several sub-phases are known from northern Germany (Eissmann, 2002; Litt et al., 2007; Ehlers et al., 2011; Stephan, 2014). These repeated ice advances of the Middle Pleistocene Saalian glaciation are generally correlated with MIS 6 and are referred to as Drenthe and Warthe ice advances (Litt et al., 2007; Ehlers et al., 2011). However, there is increasing evidence of an extensive earlier Saalian ice advance during MIS 8 (Beets et al., 2005; Kars et al., 2012; Roskosch et al., 2015).

Along the Middle Pleistocene Saalian ice-sheets numerous ice-dammed lakes formed in the southern North Sea basin (Gibbard, 2007; Busschers et al., 2008; Cohen et al., 2014, 2017), the Netherlands (Beets and Beets, 2003; Busschers et al., 2008; Laban and van der Meer, 2011), Germany (Eissmann, 1975, 2002; Gassert, 1975; Thome, 1983; Klostermann, 1992; Junge, 1998; Winsemann et al., 2003, 2004, 2007a, b, 2009, 2011a, b, 2016; Meinsen et al., 2011) and Poland (Marks, 2011; Salamon et al., 2013; Marks et al., 2016). However, the size and volume of many

* Corresponding author.
E-mail address: lang@geowi.uni-hannover.de (J. Lang).

https://doi.org/10.1016/j.quascirev.2017.11.029

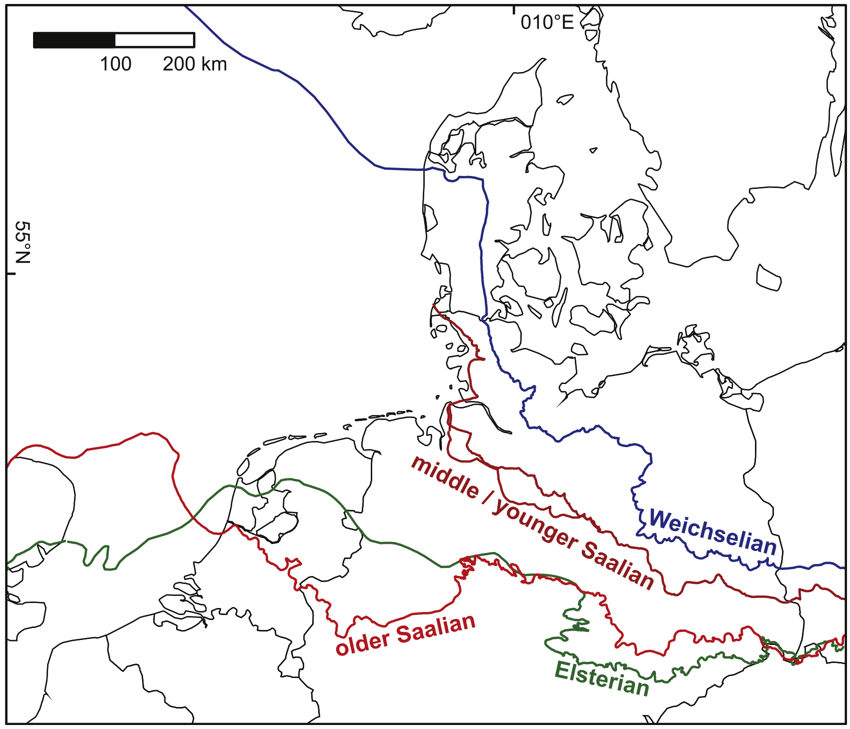

Fig. 1. Overview map, showing the maximum extent of the Middle and Late Pleistocene ice advances. Ice margins are based on Ehlers et al. (2011), Winsemann et al. (2011b) and Moreau et al. (2012).

of these lakes are commonly underestimated because the reconstructions were based on lake-bottom sediments only (Junge, 1998; Eissmann, 2002).

Ice-dammed lakes interact with the dynamics of ice sheets, meltwater and sediments and exert an important control on ice-sheet dynamics by accelerating the ice flow and the loss of ice mass (Stokes and Clark, 2004; Winsborrow et al., 2010; Carrivick and Tweed, 2013; Perkins and Brennand, 2015; Sejrup et al., 2016). Ice streams may be triggered by the effects of proglacial lakes on glacier dynamics (Stokes and Clark, 2003, 2004; Meinsen et al., 2011; Winsemann et al., 2011b). The opening of outlets during ice retreat may cause glacial lake-outburst floods, which have an enormous impact on the subsequent landscape and drainage evolution (Baker, 1973; Gibbard, 2007; Gupta et al., 2007, 2017; Meinsen et al., 2011; Carling, 2013; Collier et al., 2015; Winsemann et al., 2016). The removal of large ice-masses during glacial lake-outburst floods will further destabilise the ice margin, trigger local re-advances and finally contribute to the decay of an ice sheet (Stokes and Clark, 2004; Meinsen et al., 2011; Winsemann et al., 2011b; Sejrup et al., 2016).

The aim of this study is to provide a comprehensive palaeogeographic reconstruction of the spatio-temporal evolution of ice advances, ice-margin configurations and ice-dammed lake systems along the southwestern margin of the Middle Pleistocene Saalian Fennoscandian ice sheets. New and previously published numerical ages are integrated with data on palaeo-ice flow directions and till provenance. The extent and evolution of ice-dammed lakes is based on a detailed facies analysis of ice-marginal deposits, the mapping of fine-grained lake bottom sediments and the mapping of lake-overspill channels.

2. Regional setting

The study area stretches along the former southwestern margin of the Middle Pleistocene Fennoscandian ice sheets (Fig. 1), where the river valleys of the Central German Uplands pass northwards into the low-relief area of the North German Lowlands. The terrain of the Central German Uplands is characterised by up to 400 m high bedrock ridges and relatively steep river valleys. Extensive low relief areas are formed by the Lower Rhine Embayment and the Münsterland Embayment in the west and the Halle-Leipzig lowland area in the east. Most of these bedrock ridges trend WNW to ESE and comprise Mesozoic or Palaeozoic rocks. A distinct west-east division of the study area is caused by the NWN to ESE trending Palaeozoic rocks of the Harz Mountains. The river courses are mainly directed towards the northwest (Fig. 2).

The study area has been affected by multiple ice advances during both the Elsterian and Saalian glaciations. From the Elsterian glaciation two major ice advances are known, which advanced to approximately the same maximum position (Eissmann, 1975, 1994, 1997, 2002; Litt et al., 2007; Ehlers et al., 2011; Roskosch et al., 2015). These ice advances probably occurred during MIS 12 and MIS 10 (Gibbard and Cohen, 2008; Litt et al., 2008; Ehlers et al., 2011; Böse et al., 2012; Lang et al., 2012; Lee et al., 2012; Roskosch et al., 2015). The Saalian Complex in northern central Europe spans MIS 8 to MIS 6 (Fig. 3; Litt et al., 2008). The maximum extent of the Saalian ice cover was reached during the older Saalian glaciation, while the middle and younger Saalian glaciations had lesser maximum extents (Fig. 1; Ehlers et al., 2011). The older Saalian glaciation is commonly referred to as the Drenthe ice advance, while the middle and younger Saalian glaciations are referred to as Warthe ice advances (Litt et al., 2007; Ehlers et al., 2011; Laban and van der Meer, 2011), although the middle Saalian ice advance is locally also referred to as the younger Drenthe ice advance (Hoffmann and Meyer, 1997; Meyer, 2005).

The Saalian glacigenic deposits include subglacial tills, coarse-grained meltwater deposits and fine-grained lake-bottom sediments. Beyond the limits of glacigenic deposition the glaciations